The Stability of Immediate Implant Placement in Posterior Region: a Six-Month Study

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Abstract

The purpose of this study was to evaluate implant stability change during the healing period after immediate implant placement, in order to determine the appropriate time for implant loading in the posterior teeth. The hydrophilic SLA surface tapered implants were immediately placed after posterior teeth extraction. The stability of the implants was obtained using resonance frequency analysis, and presented using implant stability quotient (ISQ) values. The stability measurements were performed immediately after placement (0 week), and at 1 week, 2 weeks, 4 weeks, 8 weeks, 12 weeks and 24 weeks after implant placement, respectively. The implants achieved prosthesis after 6 months of placement. A total of 23 patients with 23 implants were included in this study. After immediate placement, all the implants had high primary stability (ISQ=74.03±5.63). The ISQ values were observed to be lowest 4 weeks after placement (71.82±6.17) before gradually increasing over the 24-week measurement period (81.59±3.94). There was a significant correlation (p<0.001) found between mean ISQ and time. The present study demonstrates that implant stability change is correlated with time, with all the immediate implants placed in posterior teeth having high primary stability. The implant stability gradually decreased over 4 weeks, before gradually increasing until week 20, and subsequently decreasing thereafter. During the healing period, implant stability did not decrease below an ISQ 70, indicating high stability that is sufficient for immediate loading.

Keywords: *Dental implant/ Osseointegration/ Resonance frequency analysis/ Tooth extraction*

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Introduction

Dental implants have become a popular choice to replace missing teeth due to their high success rate. The successful implants have to achieve and maintain stability. The stability of an implant is defined as the absence of clinical mobility; however, an implant retains micro-movement when a load is applied. There are several directions of load during implant function (axial, lateral and rotational), with a stable implant displaced in the direction of load before returning back to its previous position when the load is removed. The stability of implant is crucial for the implant survival. [1]

Implant stability can be measured using several methods including clinical perception, percussion test, reverse torque test, cutting torque resistance analysis, Periotest and resonance frequency analysis (RFA).[2]

The RFA technique is a widely non-invasive implant stability analysis method. It has been used in several recent experimental and clinical studies. The principle of RFA is to apply lateral force to an implant with radio frequency to establish implant micro-movement and provides information about the stiffness of the implant surface and the contact bone.[1, 2]

The RFA technique involves attaching a small transducer made of commercially pure titanium, directly attached to the implant fixture. The transducer contains 2 piezoceramics, one is excited with a sinusoidal signal to vibrate the transducer, and the flexural resonance frequency is observed by the other piezoceramic. The output signal is amplified by a charge amplifier before interpretation, while the excitation signal is produced by the frequency response analyzer, which produces and receives the amplified output signal via personal computer. The excitation signal is a sine wave varying in frequency from 5 to 15 KHz with a peak

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amplitude of 1 volt. The measurement outcome is a resonance frequency at peak amplitude when the frequency is plotted against the amplitude of the output signal, reflecting the micro-mobility of the implant. A greater resonance frequency implies less implant micro-movement.[1,3]

The early generation RFA devices were not suitable for chairside usage due to the large amount of cord and equipment size, whereas the new generation of RFA devices have been developed to be cordless and convenient to use. The transducer is a small metallic rod with a magnet on top, which is attached directly to the implant fixture by screwing into the inside thread of the implant. The frequency response analyzer is a wireless probe, which produces a magnetic pulse to excite the magnet by vibration, inducing an electronic voltage in the probe coil.[1,2] The resonance frequencies of the implant are achieved and calculated via a mathematical algorithm and displayed as an "Implant Stability Quotient (ISQ)". The ISQ is an arbitrary unit, ranging between 0 and 100, used instead of the resonance frequency expressed in KHz for convenience. Therefore, the ISQ corresponds with the resonance frequency.[1,4]

The ISQ is related to implant micro-movement[5,6], with a higher ISQ indicating a high implant stability. A number of studies have reported implants with an ISQ value less than 60 to indicate low stability and a sign to continue monitoring. Alternatively, implants with an ISQ value of more than 70 suggests high stability and the ability to perform immediate loading.[7-10]

The stability of implant consists of primary stability and secondary stability. The primary stability of an implant is achieved upon the mechanical engagement of the implant with the surrounding bone, a requisite for successful osseointegration. The factors affecting primary stability include bone quality and quantity, and the surgical technique and implant design, whereas secondary stability depends on primary stability, bone remodeling and implant surface design.[11] During the healing process, primary stability decreases and is substituted with secondary stability, i.e., osseointegration. Therefore, there is a period when the implant has a low stability before it gradually increases[12], this transition period is critical and may affect the success of the implant.

In general, after tooth extraction, the tooth socket will be left for at least 4 months to heal before implant placement. The healed bone provides a better quality and quantity of bone, nevertheless it is a long waiting period for the implant patients, and hence the immediate implant placement protocol is an alternative option.[13]

The immediate implant placement refers to the implant placement immediately following tooth extraction. A potential advantage to the patient is that immediate implant placement can be performed under the same surgical procedure as the tooth extraction. Therefore, it can reduce the number of surgical procedures, reduce overall treatment time, and produce the optimal availability of existing bone. However, there are also several disadvantages; it does not create an optimal implant placement and anchorage, it compromises the optimal outcome due to the thin biotype, there is a potential lack of keratinized mucosa for flap adaptation, an adjunctive procedure may be required, and technique sensitivity.[13] There is a 98% survival rate after immediate implant placement in the posterior teeth, but there is no significant difference in implant survival when comparing immediate to delayed molar implant placement.[14,15]

It is known that bone quantity and quality are associated with primary stability, which is necessary for the secondary stability[10], with the tooth socket after tooth removal, having a lower quantity and quality of bone. Smith and Tarnow (2013)[16] classified the molar extraction site for immediate implant placement into three types: type A socket, which has adequate septal bone for complete engagement of the implant; type B socket having a septal bone within the socket but not enough to circumferentially contain the implant; and a type C socket, with no septal bone to stabilize the implant, so it engages with the surrounding walls of the socket. The use of immediate implants has the benefit of reducing treatment time: however, there is more concern about stability, especially in posterior teeth, where the wide gap between the implant and tooth socket may compromise its stability.[16]

The purpose of this study was to evaluate implant stability change during the healing period after immediate implant placement, in order to determine the appropriate time for implant loading in the posterior teeth.

Materials and Methods

The subjects were dental patients who attended the Faculty of Dentistry, Mahidol University for treatment. The inclusion and exclusion criteria are shown in Table 1.

The study was approved by the local ethics committee (Faculty of Dentistry/Faculty of Pharmacy, Mahidol University, Institutional Review Board, COA. No. MU-DT/PY-IRB 2017/029.2804). All subjects had the study procedures explained and provided the written informed consent to participate in this study. CBCT was taken in all subjects for proper treatment planning.

Table 1 Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
1. Age >18 years.	1. Smoking (≥10 cigarettes/day).
2. ASA Cl. I or II.	2. Pregnancy.
3. Posterior tooth (premolar or molar tooth) required extraction due to unrestorable or crown-root fracture with planned replacement with a dental implant.	3. Received immunosuppressant drugs.
	4. Received bisphosphonate drugs.
	5. History of head and neck radiation.
	6. Severe chronic periodontitis tooth.
	7. Active infection in the area of implant placement.

The surgical procedures were performed by one experienced surgeon. The surgery was performed under local anesthesia, and the tooth removed using a less traumatic technique (Figure 1a). Implant placement was performed immediately after tooth removal. The implants used were Titanium-Zirconia alloys (Roxolid®, Straumann®, Switzerland), bone level tapered implants with hydrophilic SLA surface (SLActive®, Straumann®, Switzerland) and a 4.1 or 4.8 mm diameter, and 10 or 12 mm length. The osteotomy was prepared according to the manufacturer's guidelines (Figure 1b). The position of the implants was followed the ideal prosthetic position, engaged with the septal bone in a multi-root tooth, or surrounding bone socket wall, and 2-3 mm below the tooth socket (Figure 1c).

After implant placement, the implant stability was determined with an RFA device (Mega ISQ™, MEGA'GEN, South Korea). The transducer (Smartpeg™, Osstell AB, Sweden) was screwed into the implant fixture until it was finger tight (Figure 2a, 2b). The RFA device probe was then held perpendicular to the tip of transducer without any contact (Figure 2c), and the device measured the implant stability, which was displayed in ISQ units. The implant was measured in 4 directions; buccal, lingual, mesial and distal, respectively. The measurement was repeated 3 times at each site and the mean value was calculated. The implant stability was recorded as the average ISQ over the 4 directions.

The gap between the implant fixture and tooth socket was filled with bone graft (Cerabone®, botiss, Germany) (Figure 1d). The customized healing abutment was fabricated with a Ti-base (Variobase®, Straumann, Switzerland) and bis-acryl (Protemp™ 4, 3M ESPE, Germany) to cover the tooth socket with no contact to the opposing tooth (Figure 1e & f).

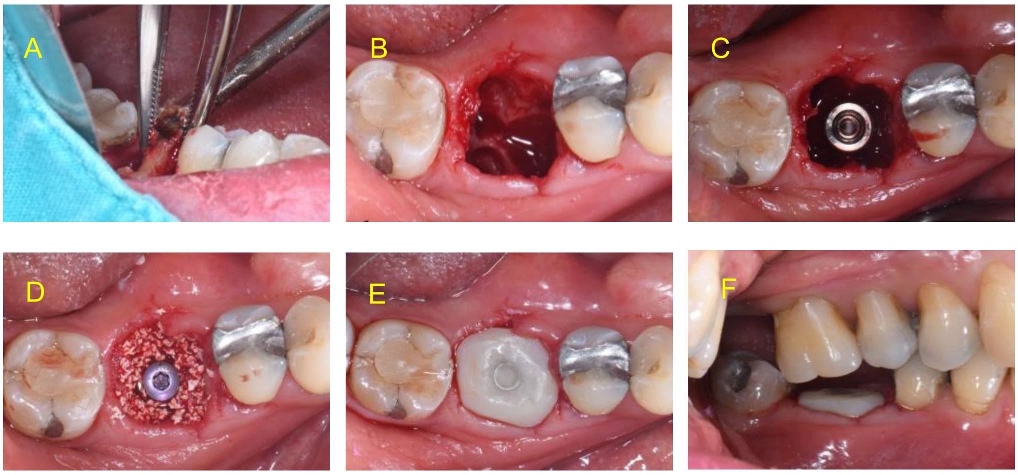

Figure 1 (A) Less traumatic tooth removal. (B) Tooth socket was prepared for implant placement according to the manufacture's protocol. (C) Implant placement. (D) The gap was filled with bone graft. (E) The customized healing abutment was inserted. (F) There was no any contact with healing abutment of implant.

Figure 2 (A) The transducer was screwed into the implant fixture with the holder. (B) The transducer attached to the implant fixture. (C) The RFA device probe was held perpendicular to the tip of transducer without any contact.

Patients were followed up after implant placement, and the ISQ measurements were performed during these visits. The healing abutment was removed and the transducer was attached to measure the ISQ following the measurement protocol. The ISQ measurement was performed by one operator and recorded at 0 week (immediately after implant placement), 1 week, 2 weeks, 4 weeks, 8 weeks, 12 weeks and 24 weeks, respectively. After 6 months post-implant placement, the prosthesis was achieved by a prosthodontist. Statistical analysis was conducted using a linear mixed model (SAS Studio 9.2, SAS institute) to analyze the relationship between implant stability (ISQ) and the 7 time points after implant placement. All data are expressed as mean ± standard deviation (SD.)

Results

A total of 23 patients (13 females and 10 males) aged 50.1 years (range: 26 to 72 years) volunteered to take part in this study. A total of 6 premolars and 17 molars were extracted and replaced with implants immediately after extraction. The reasons related to tooth extraction included unrestorable (73.9%) and crown-root fracture (26.1%). A total of 8 implants were placed in the maxilla and 15 implants were placed in the mandible, with no implant failures.

The stability of the implants, as ISQ, were obtained immediately after implant placement and recorded at week 0. The implants were followed up and measured at 1, 2, 4, 8, 12, and 24 weeks after implant placement. The implant placement was divided into 2 groups; the first group had implants placed in the maxilla, and the second group had implants placed in the mandible. The outcomes are shown in Table 2.

Table 2 The mean ISQ and standard deviation at each observational time point.

Week	Maxilla		Mandible		All sites	
	N	Mean ISQ ± SD	N	Mean ISQ ± SD	N	Mean ISQ ± SD
0	7	76.07 ± 4.11	15	73.08 ± 6.10	22	74.03 ± 5.63
1	8	73.38 ± 4.23	15	73.17 ± 6.08	23	73.24 ± 5.41
2	5	74.50 ± 3.22	9	70.42 ± 6.29	14	71.88 ± 5.63
4	7	75.46 ± 3.25	15	70.12 ± 6.54	22	71.82 ± 6.17
8	5	77.25 ± 3.96	7	79.07 ± 5.36	12	78.31 ± 4.72
12	8	78.16 ± 3.22	15	78.92 ± 4.69	23	78.65 ± 4.17
24	8	80.16 ± 3.86	15	82.35 ± 3.89	23	81.59 ± 3.94

After implant placement, all the implants had high primary stability with an ISQ>70 (74.03±5.63). The ISQ gradually decreased to its lowest value after 4 weeks (71.82±6.17) before rapidly increasing until 8 weeks post placement. Subsequently, the ISQ was observed to gradually increase (Figure 3).

Considering the stability of implant placement in each arch. After the first week, the ISQ of the implant placed in the maxilla decreased to its lowest value (73.38±4.23) before gradually increasing until week 24 (Figure 3). In the mandible, the ISQ slightly changed over the first week after placement, before rapidly decreasing at the 2 weeks, and reaching its lowest value at 4 weeks (70.12±6.54). The ISQ rapidly increased during week 4 to 8, before gradually increasing until week 24 (Figure 3). In comparing the implants placed in maxilla and mandible using the unpaired t-test, there was no significant difference found between implant placed in maxilla or mandible at 1, 2, 4, 8, 12 weeks (p = 0.28, 0.14, 0.07, 0.32, 0.63, respectively). But at the end point of observation (24 weeks), the ISQ of the mandible implant (82.35±3.89) was higher compared with the implant placed in the maxilla (80.16±3.86) with a statistically significant difference (p=0.02).

The correlation between implant stability (ISQ) and time was performed using a linear mixed model; the equation is presented in Table 3.

It was found that the correlation between implant stability and time was statistically significant (p <0.001), with stability initially decreasing and reaching its lowest value at week 4, before reaching its highest value at week 20 (Figure 4). In regard to placement location (maxilla and mandible), the stability changed over time in the mandible with statistically significant (p<0.001) as the curvilinear relationship; however, the correlation between maxillary implant stability and time was also statistically significant (p=0.04) but was not the curvilinear relationship as in mandible (Table 3) (Figure 4).

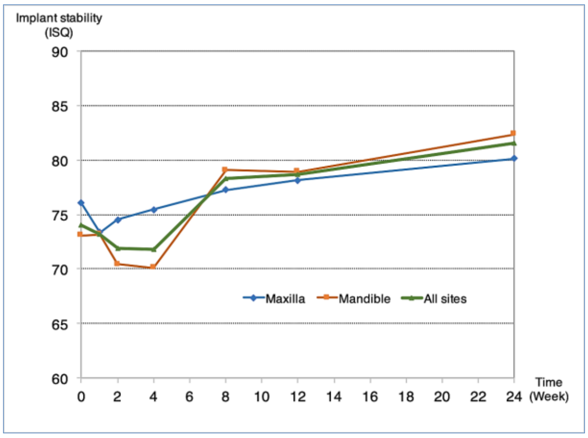

Figure 3 The ISQ changed over the time.

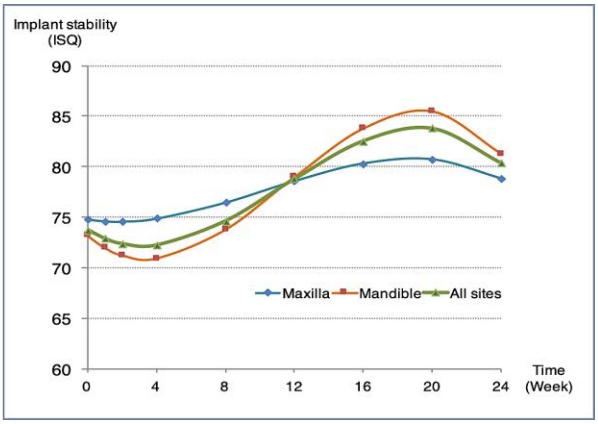

Figure 4 The correlation between the implant stability (ISQ) and time (Week).

Table 3 The linear mixed model equation.

Linear mixed model equation	
ISQ of all site implants*	$= 73.76 + 0.7821t + 0.07183t^2 - 0.00559t^3$
ISQ of implants placed in maxilla†	$= 75.68 + 0.4641t + 0.02649t^2 - 0.00225t^3$
ISQ of implant placed in mandible‡	$= 72.91 + 1.0089t + 0.09850t^2 - 0.00737t^3$

t= week-7 * coefficient p-value of $t, t^2, t^3 < 0.001$

† coefficient p-value of $t, t^2, t^3 = 0.04, 0.38, 0.26$ respectively

‡ coefficient p-value of $t, t^2, t^3 < 0.001$

Discussion

The main findings of the present study found that a correlation exists between implant stability and the time after immediate implant placement.

The present study demonstrated that the immediate implant placement in the posterior tooth, had a high primary stability. We observed the primary stability to be higher compared with previous studies conducted in the anterior and premolar teeth.[17] It may be speculated that this is related to the majority of posterior teeth bone sockets having a septal bone for implant engagement, while the bone sockets of anterior teeth, and mandibular premolars, have no septal bone. Thus, they have to engage with the surrounding bone wall, as the type C socket provides less primary stability.[16]

After implant placement, the primary stability gradually decreased over the course of the wound healing process, and was replaced with the secondary stability. So, there would be the implant stability dip period. The present study found that after placement, implant stability gradually decreased over the initial 4 weeks before subsequently increasing.

Lang et al. (2011)[18] studied the histological change around hydrophilic SLA surface implant placed in human bone. After 2 weeks, the beginning apposition of new bone was visible over large areas of the implant surfaces. After 4 weeks, new bone was found coating a thin layer on both the implant surface and old bone, and the struts of woven bone trabeculae extending from the old bone towards the implant surface. An advanced stage of bone maturation was indicated after 6 weeks. In comparison to study in the anterior and premolar teeth,[17] we presently observed implant stability increasing after 4 weeks. This longer delay may be due to the wide gap between the implant surfaces and bone socket of posterior tooth. The newly formed bone appeared to be extending from the old bone, as a tooth socket to the implant surfaces, possibly indicating that more time is required for new bone formation to fill the wide gap.

After 4 weeks of placement, the implant stability rapidly increased until 20 weeks, before decreasing as a consequence of bone remodeling.[18] In the present study, we only used a 6-month follow up of the patients, therefore further studies may be designed to observe the change of implant stability over an extended period.

There was a study compared the stability between immediate loading and early loading of the implant placed in healed site in posterior mandible. The mean value of primary implant stability was ISQ 76.92±0.79. No statistically significant differences were found between groups along 52 weeks of observation. After 5 years of follow up, the survival rate of both groups was 100%. The study concluded that the ISQ value more than 70 indicated high implant stability and could be immediate loading.[8]

Despite having a period when implant stability decreased in the present study, the stability of all immediate implants remained higher than an ISQ of 70, indicating high stability, which suggests that immediate loading of the implant can be performed.[7-10]

The immediate implants placed in the posterior maxilla had high primary stability and a generally less change in implant stability over the healing period. The stability of the implants was slightly decreased during the first week after initial placement before increasing. The secondary stability relates to bone formation cells[12], with the maxilla exhibiting greater blood supply that can deliver more cells into the wound. This may explain why the stability of the immediate implants placed in the maxilla had less stability change compared with the mandible. At 24 weeks after implant placement, the implant surrounding bone was complete healing, the mandible was higher bone density compared with the maxilla[19], so higher implant stability was observed in mandible.

In line with the traditional loading protocol, implants are typically left with no force applied after placement for a period of 3 months in the mandible, and 6 months in the maxilla. The excessive forces on the implants during the healing period may jeopardize the osseointegration.[20-22] The implants should only be loaded when it achieves complete osseointegration, or in other words, when the implant has adequate stability. The present study showed that the immediate implant placed in posterior teeth had high implant stability. Although there was a decrease in stability over the initial 4 weeks period after placement, the implant stability did not fall below a value of ISQ 70 during the healing period, indicating immediate loading can be applied.[7-10] The implant stability change after immediate loading of posterior immediate implant is interesting, and is worthy of further study. Finally, in regard to the timing of prosthesis fabrication, besides the stability of implant, the healing of the surrounding soft tissue around the implant could be considered to be both aesthetic and functional.

Conclusion

The present study demonstrates that implant stability change is correlated with time, with all the immediate implants placed in posterior teeth having high primary stability. The implant stability gradually decreased over 4 weeks, before gradually increasing until week 20, and subsequently decreasing thereafter. During the healing period, implant stability did not decrease below an ISQ 70, indicating high stability that is sufficient for immediate loading. For further study, immediate loading after immediate placement may be considered.

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ความเสถียรของรากฟันเทียมแบบฝังทันทีในฟันหลังในระยะเวลา 6 เดือน

บงกช สมราช วรพงษ์ ปัญญายงค์* บุณฑริกา ชื่นจิตกุลถาวร* ปริญญา อมรเศรษฐชัย* ศุภชัย สุพรรณกุล**

บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อติดตามและวิเคราะห์การเปลี่ยนแปลงความเสถียรของรากฟันเทียมแบบฝังทันทีในฟันหลัง เพื่อประโยชน์ในการหาเวลาที่เหมาะสมที่จะเริ่มให้แรงแก่รากฟันเทียม ในการศึกษานี้ได้ทำการฝังรากฟันเทียมรูปทรงสอบชนิดไฮโดรฟิลิกเอสแอลเอทันทีหลังการถอนฟัน จากนั้นทำการวัดความเสถียรของรากฟันเทียมด้วยวิธีการวัดการสั่นพ้องของคลื่นเสียง ซึ่งแสดงผลเป็นค่าไอเอสคิว การวัดค่าความเสถียรของรากฟันเทียมจะทำทันทีหลังการฝังรากฟันเทียม และเมื่อติดตามผลที่ 1, 2, 4, 8, 12 และ 24 สัปดาห์หลังการฝังรากฟันเทียม จากนั้นจึงทำครอบฟันบนรากฟันเทียมให้แก่ผู้ป่วย การศึกษาครั้งนี้ได้ทำการฝังรากฟันเทียมจำนวน 23 ซี่ ในผู้ป่วยจำนวน 23 ราย พบว่ารากฟันเทียมแบบฝังทันทีทุกซี่มีความเสถียรปฐมภูมิที่ดี โดยวัดค่าไอเอสคิวได้มากกว่า 70 (74.03 ± 5.63) จากนั้นทำการติดตามผล พบว่าค่าไอเอสคิวลดลงหลังการฝัง จนมีค่าไอเอสคิวต่ำสุดที่ 4 สัปดาห์หลังจากฝังรากฟันเทียม (71.82 ± 6.17) จากนั้นจึงเพิ่มขึ้นจนถึงจุดสิ้นสุดของการศึกษา (สัปดาห์ที่ 24) โดยวัดค่าไอเอสคิวที่จุดสิ้นสุดของการศึกษาได้ 81.59 ± 3.94 ค่าไอเอสคิวมีความสัมพันธ์กับเวลาอย่างมีนัยสำคัญทางสถิติ ($p < 0.001$) จากการศึกษาสรุปได้ว่ารากฟันเทียมแบบฝังทันทีในฟันหลังมีความเสถียรปฐมภูมิที่ดี โดยพบว่าความเสถียรของรากฟันเทียมมีความสัมพันธ์กับเวลา แม้จะมีช่วงที่ความเสถียรตกลง แต่ก็ยังคงอยู่ในระดับที่มีความเสถียรสูง (ไอเอสคิวมากกว่า 70) ซึ่งสามารถทำการให้แรงแก่รากฟันเทียมได้ทันที

คำไขรหัส: *รากฟันเทียม/ การเชื่อมประสานของผิวรากฟันเทียมกับกระดูก/ การวัดการสั่นพ้องของคลื่นเสียง/ การถอนฟัน*

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